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An Overview of ARL's Multimodal Signatures Database and Web Interface

by Kelly Bennett, Sam Wen, and James Robertson

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14. ABSTRACT
The U.S. Army Research Laboratory (ARL) Multimodal Signatures Database (MMSDB) is a centralized collection of sensor data of various modalities that are co-located and co-registered. The signatures include ground and air vehicles, personnel, mortar, artillery, small arms gunfire from potential sniper weapons, explosives, and many other high value targets. This data is made available to Department of Defense (DoD) and DoD contractors, Intel Agencies, other government agencies (OGA) and academia for use in developing target detection, tracking, and classification algorithms and systems to protect our Soldiers. A platform independent Web interface disseminates the signatures to researchers and engineers within the scientific community. Hierarchical Data Format 5 (HDF5) signature models provide an excellent solution for the sharing of complex multimodal signature data for algorithmic development and database requirements. Many open source tools for viewing and plotting HDF5 signatures are available over the Web. Future development includes extending the Web interface into a portal system for accessing ARL algorithms and signatures and High Performance Computing (HPC) resources.

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Multimodal signatures, database, Web interface, platform independence, Hierarchical Data Format 5 (HDF5), Java, distributed computing, interactive, Servlets, JSP

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Acknowledgement

This report is dedicated to our colleague, V. Anh Nguyen. Every time we walk into the Acoustic Library and see Anh's plaque hanging on the wall, we pause and think about the early contributions Anh made to our database program. Although many of us never worked with her directly, a few have had the privilege of reading her unpublished notes she left behind on the acoustic database. She was truly a gifted researcher and it is an honor to take the database effort she started and to turn it into a major program within the Signal Image Processing (SIP) division. This report is dedicated to her memory.

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1. Introduction

The sharing and distributing of signature data and algorithms enhances and promotes the quality and depth of research and development within the scientific community. A long-standing obstacle in sharing data with different organizations is the variety of proprietary data formats used by organizations or the subgroups within them. Aside from the data formats, other difficulties encountered with data sharing are due to software tools that are technically difficult to install on remote computers and may involve license agreement issues in the distribution process of the software. Additional issues include incompatibility between client and server platforms (operating systems and application software) as well as configurations and components such as the Web server and database management software and applications.

A solution to the *true sharing and accessibility* of scientific multimodal signature data is to develop a software system that is platform and Internet browser independent and will provide the data in a format common to researchers and engineers within the scientific community. Java, an open source fully object-oriented software language, provides excellent platform independence. It also provides integration with Hypertext Markup Language (HTML) to create an interactive and dynamic online experience for interfacing with databases and creating portals for accessing algorithms on computational engine servers. Java servlets and JavaServer Pages (JSPs) combine to provide Web access to online database signatures and algorithms with server side processing that does not require special software components installed on a client machine. Access to the Internet and a Web browser is the only requirement.

In addition to a platform independent Web infrastructure that provides *true accessibility* of information over the Internet, a versatile and portable data model and file format is necessary to provide *true sharing* of multimodal signature data and ancillary signature information among various organizations. The file format must be open source and capable of accommodating large signature files along with metadata (ground truth, meteorological information, sensor parameters, etc.). An excellent choice is Hierarchical Data Format 5 (HDF5). HDF5 provides all of the features necessary to support our signature database and algorithmic development requirements.

This report details an overview for providing a *true sharing and accessibility* of ARL's multimodal signatures and ancillary information, a Java Web interface, and general description of the multimodal signatures database (MMSDB) and design. It is not intended to be a detailed users manual of the Web interface or a comprehensive design document detailing the design of the multimodal signatures database.

2. Background

In the late 1990's, the U.S. Army Research Laboratory (ARL) embarked on the development of a multiuser client/server interface with an acoustic database based on client-side processing running on the ARL local area network (LAN) (*1*). The system developed was limited in network accessibility across wide area networks (WAN) as well as platform independence. The LAN client/server interface approach was intended for demonstration purposes rather than actual deployment. The method of creating a Structured Query Language (SQL), based on targets, sensors, data collections, and meteorological conditions through a modular graphical user interface, proved to be an excellent intuitive method of interfacing the database with the end user. The following points describe the limitations of the initial client/server interface and database design.

a. Database strictly designed for acoustic and seismic modalities with little flexibility to expand to other modalities.

b. User interface strictly designed as a LAN application.

c. Interface designed for client-side processing and running on a Windows only operating system (OS), which severely limits platform independence.

d. Installation and/or updates to the client software required either downloading an installation file over the network or receiving the installation file on a computer disc (CD or DVD, etc.) or other portable storage media.

e. System administration (SA) rights required to install client software.

f. User interface developed using proprietary ActiveX components, which hindered distribution due to license agreements and run-time license software to use such components.

g. Proprietary binary format of signature files made sharing of the signatures difficult.

h. Multiple files required as ancillary information to support signatures, which hindered the sharing of information.

i. Proprietary computational environments, such as MATLAB, required for algorithmic development within the user interface.

j. Client/server interface does not and cannot support High Performance Computing (HPC) and the use of such resources over the Internet.

The new Web interface and multimodal database overcome the limitations of earlier work in this area.

3. System Architecture Overview

The database consists of multimodal signature data files in the HDF5 format. Generally, each signature file contains all the ancillary information associated with the target signature. Ancillary information consists of target and event information; data collection including site information and date; sensor array information; ground truth information; sensor survey information; and meteorological information. Depending on the level of dissemination, ancillary information is modified (removed or added) to meet the appropriate dissemination level. There are four planned levels of online dissemination of the ARL multimodal signature database: online public release/unlimited distribution; Department of Defense (DoD) and DoD contractors only distribution on the Defense Research Engineering Network (DREN); Secret Internet Protocol Router Network (SIPRNET) for disseminating up to and including classified SECRET signature information; and Joint Worldwide Intelligence Communications System (JWICS) for classified top secret dissemination.

Signatures are stored on large database server hard drives with additional storage provided by directly attached storage arrays. Metadata regarding each signature is stored in the multimodal database tables that reside on the database server's primary internal hard drive. The metadata is only accessible through the Web interface for general users by performing a database query. The database is accessible to the database administrator (DBA) though software tools to perform updates and other modifications. Remote access directly to the database through the Web will be implemented in the near future though a special Web interface for database administration only by the DBA.

Users from client computers on the Internet communicate to the Web server through a Java developed Web interface to obtain access to the online multimodal database signatures. A 3-tier system separates the database, application, and the presentation tier. All the technologies that are used to develop the Web application and database management system use open source industry standards such as Apache, Tomcat, Linux, and MySQL. The Web interface uses Java technology including Java servlets and JSPs. Secure Socket Layer (SSL) provides encryption for secure communication over the Web. Figure 1 shows the overall architecture of the Web application and multimodal database system (*2*).

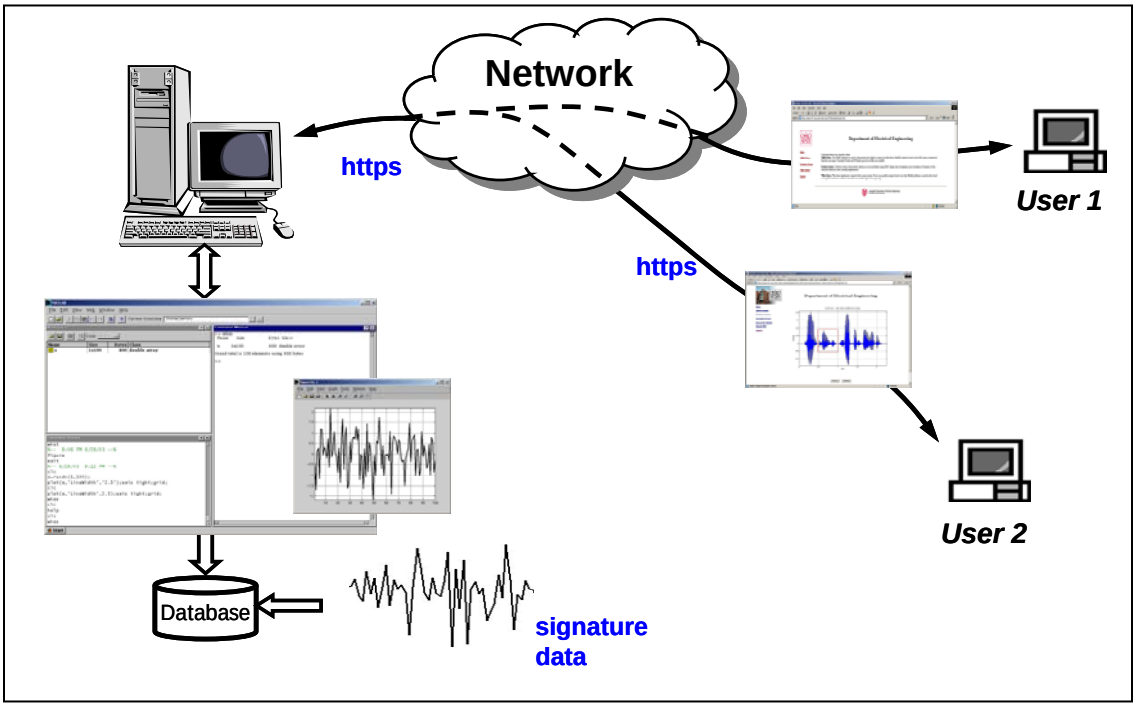

Figure 1. ARL Multimodal signatures database architecture.

The server software developed for both the application and database tier provides platform independence for the server and the client. The multimodal signatures database architecture uses either open source or proprietary operating systems and software. The present primary platform is Apache/Tomcat for the Web and application server running on either a Linux or a Mac OS X Server. Using both open source and proprietary relational database management systems, including the latest versions of Oracle and MySQL, the system was successfully tested.

The client software is extremely platform independent. By using server side processing combined with a Web interface utilizing Java technology, the new interface creates an extremely platform independent environment for client access to the MMSDB. Unlike the initial platform dependent client/server interface developed in the late 1990's, which was only usable on a client machine running a Microsoft Windows operating system, the new Web-based interface has only two requirements: access to the Internet and a Web browser of reasonably recent vintage. Table 1 shows various operating systems and browsers accessing the Web interface. The results demonstrate that many browsers running on many different operating systems, including old browsers (10 plus years old), are able to access successfully the Web interface and MMSDB.

Table 1. Results showing successful Web access to the MMSDB through the Web interface for various operating systems and browsers.

Operating System	Browser Software
Windows XP	Internet Explorer v5.0 and v6.0 with SV1
Windows XP	Mozilla Firefox 2
Windows 2000	Internet Explorer v5.0 and v6.0 with SV1
Linux Redhat 9.0	Mozilla Firefox 1.2.1
Linux Redhat 9.0	Konqueror 3.1.12
Linux Ubantu Breazy Badger and Higher	Mozilla Firefox 1.5.0.3
Linux Suse 10	Mozilla Firefox 1.0.6
Linux Suse 10	Konquereor 3.4.2
Linux Mandriva 4	Mozilla Firefox 1.0.6
UNIX Solaris 10	Netscape v7.2 and Communicator 4.0

4. Multimodal Signatures Database

Aside from moving away from client-side processing and platform dependence, another requirement is to design and develop a relational database that is capable of handling signature modalities of extreme disparity and bring together all database signature libraries within a single system. A limitation of the initial acoustic database was its inability to handle properly the metadata generated by other signature phenomenology. Without extreme modification to the interface, a necessary design feature of the new multimodal database is expandability and flexibility.

The new database design allows for easy expandability of metadata within the database tables, as well as a large amount of flexibility for the addition of database tables and changing of table key constraints. Other methodologies used in the design of the new database are minimizing metadata redundancy and maximizing referential integrity. In many ways, the new database is a collection of "living entities," where the entities can easily change to meet the needs of the multimodal signatures database requirements.

Various database design tools by Datanamic (Database DeZign and ImportER) created the entities, domains, relationships, generated SQL scripts for a vendor specific format such as Oracle or MySQL, and created a graphical data model of the database. Specially designed SQL scripts loaded the multimodal signature database tables with metadata corresponding to the HDF5 multimodal signatures. The most important aspect of the new multimodal database design is that the database tables model and correspond to actual "real world" signature phenomenology as shown in the entity diagram of the multimodal signatures database in figure 2.

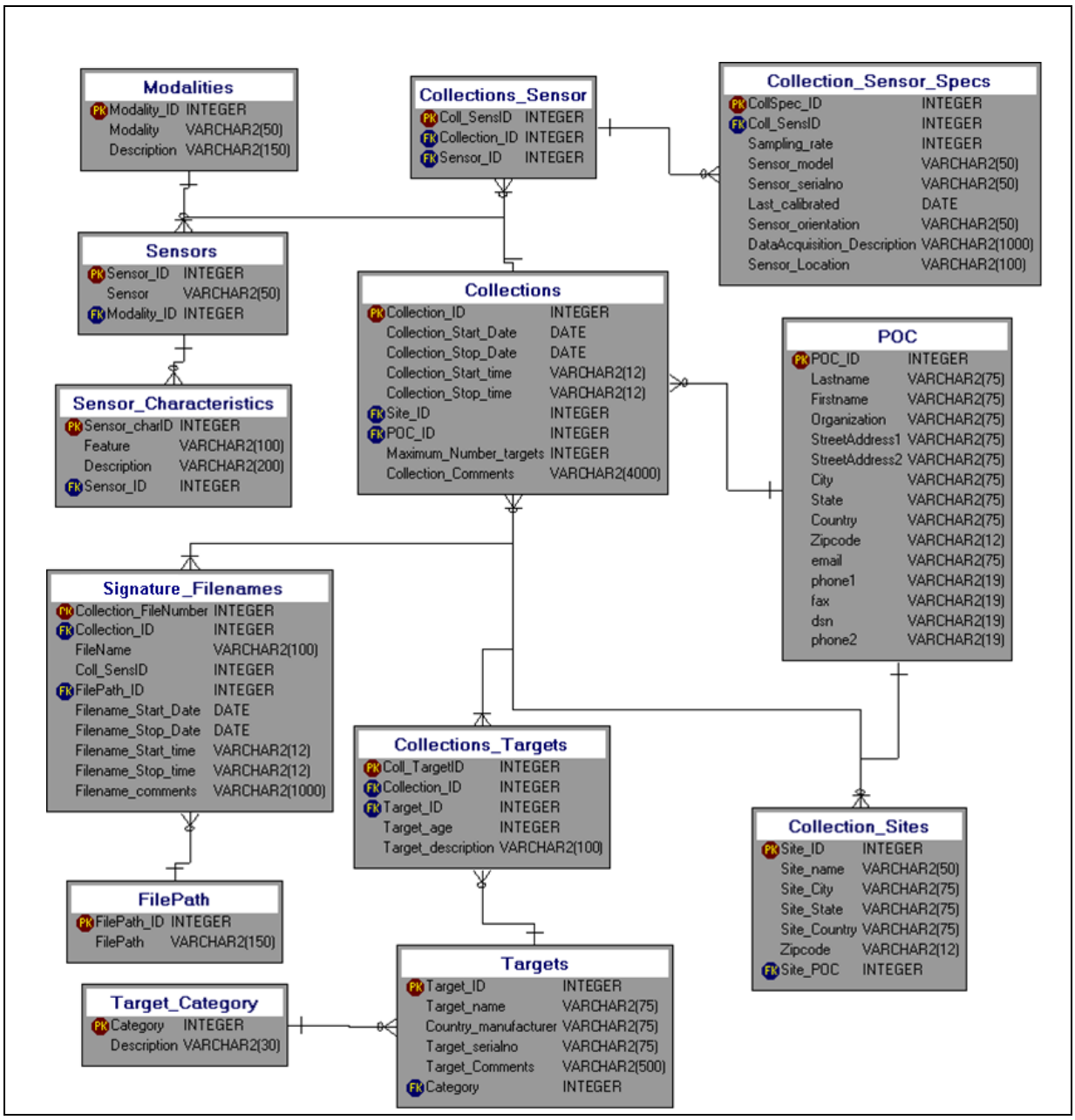

Figure 2. Entity diagram of the ARL multimodal signatures database.

5. Web Interface

The design of the Web interface to query and retrieve multimodal signatures over the Web provides data encryption with an easy to use graphical user interface (GUI). The interface allows the user to query the database and download the signature file to their local computer. Future implementations will include a portal to a computational engine (such as MATLAB) to run various signal and image processing algorithms using the various signatures in the MMSDB and return the results to the end user.

The online dissemination plan consists of four distinct dissemination levels each consisting of a Web interface, database, and HDF5 signature files that reflect the appropriate online dissemination level. Public release/unlimited distribution provides very little detailed information. The next level of online dissemination, DoD and DoD contractors only distribution on the DREN, will include the information at the public release/unlimited distribution level in addition to the detailed information permitted at the DoD and DoD contractors only level. A classified Web interface, database, and HDF5 signatures operating on the SIPRNET and JWICS will disseminate classified signatures.

The public release/unlimited distribution level of dissemination through a Web interface is presently up and running at Los Alamos National Laboratory (LANL), NM. The web site (https://infrsra.lanl.gov/ARLDB) is accessible to anyone and only contains information in the database, Web interface, and signature files that is releasable to the public.

The Web interface consists of static (HTML) and dynamic (JSP) Web pages as shown in figures 3 through 5. The Web browser displays an introductory Web page on the user's computer screen when the Web site is entered (figure 3). The user clicks on the "Search and Download Existing Data" link to generate a dynamic Web page for building a sophisticated query to search the database as shown in figure 4. The user then chooses either a single selection or multiple selections for a given searchable parameter. After choosing the desired selections, the user clicks the "Search" button to submit the query to the database engine (MySQL) to search the MMSDB for the desired signatures. The results return in the form of a dynamic Web page (JSP) as shown in figure 5. The HDF5 signatures are downloaded, one at a time, to the user's computer by right clicking on the file ID associated with a given signature file and choosing "Save Target As". After the dialog box appears (figure 6), clicking the "Save" button will download the signature file to the user's computer. Upon successful completion of the download operation, another dialog box will appear as shown in figure 7. Section 6 will present various options for viewing and working with the HDF5 signatures.

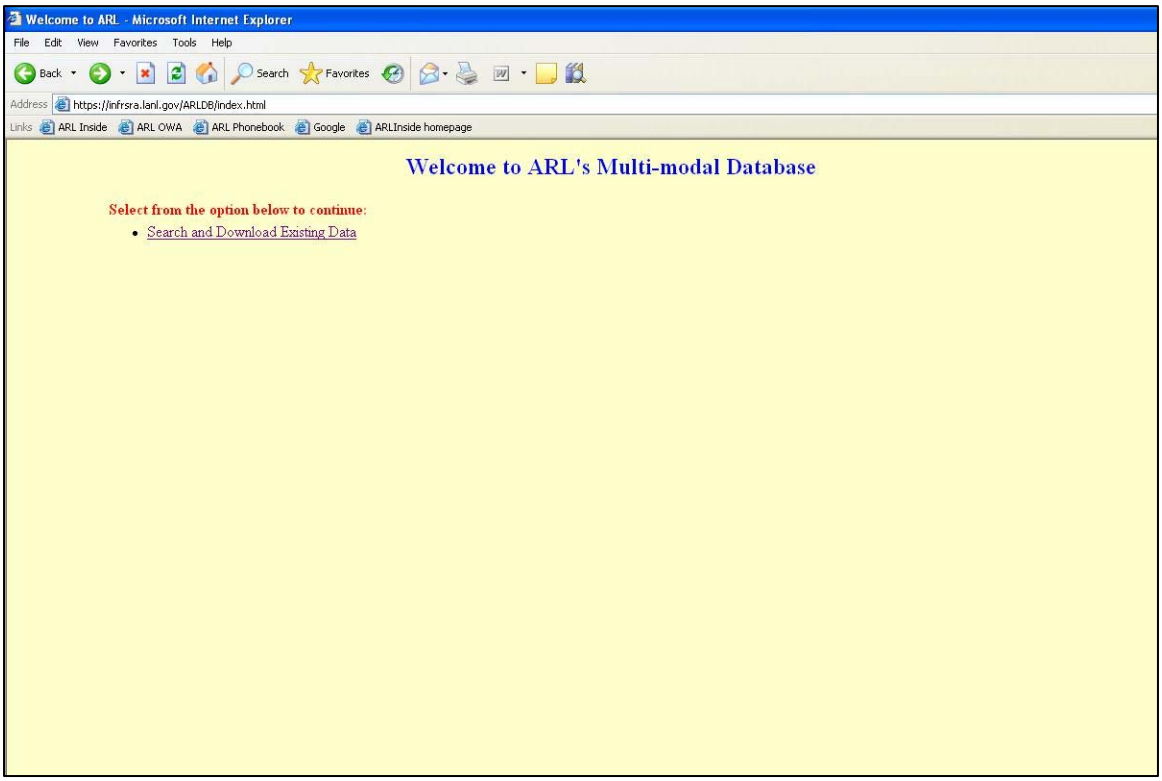

Figure 3. Welcome to ARL's Multimodal Database Web Page.

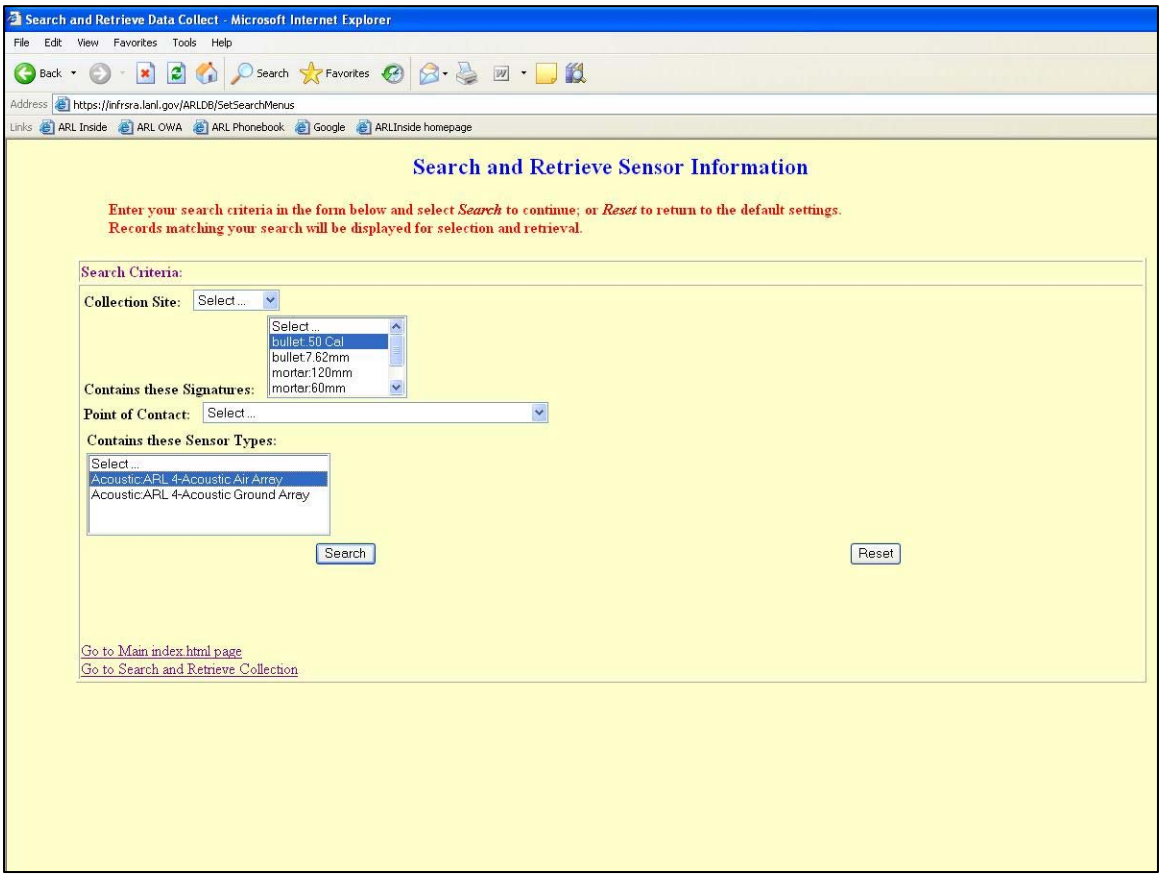

Figure 4. Signature Parameter Selection Web Page.

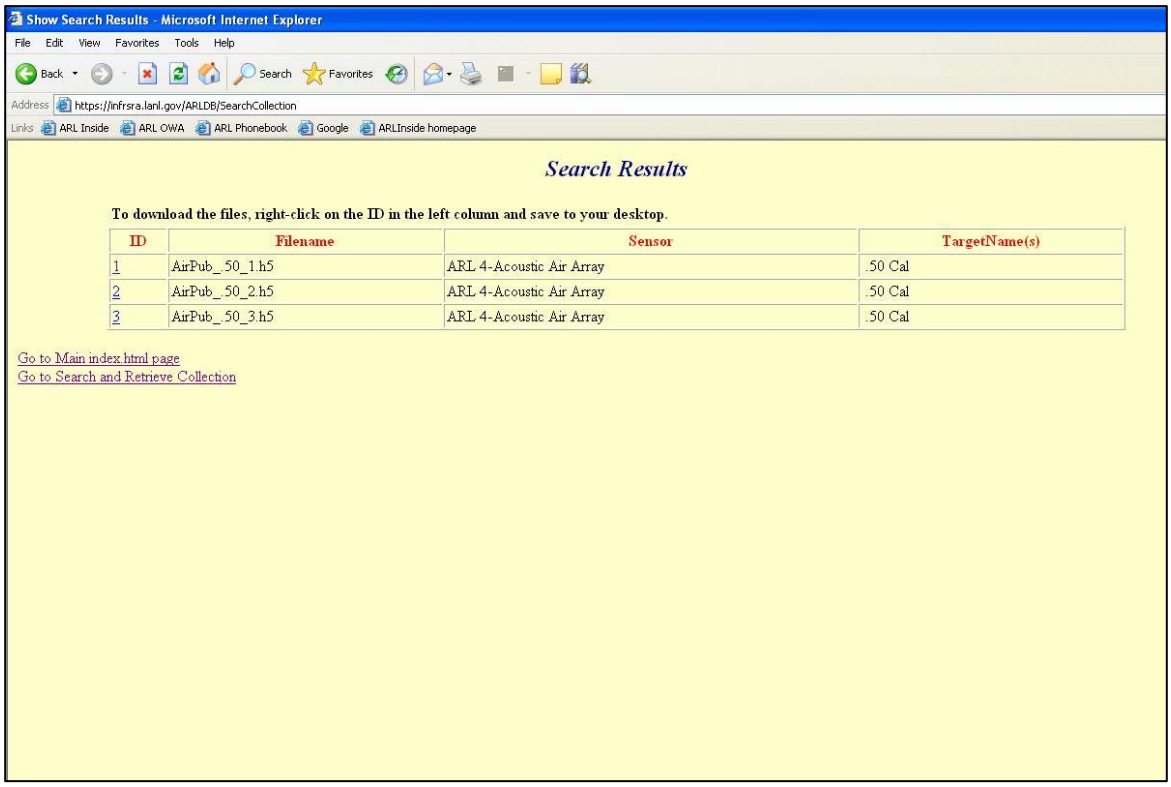

Figure 5. Search Results Web Page.

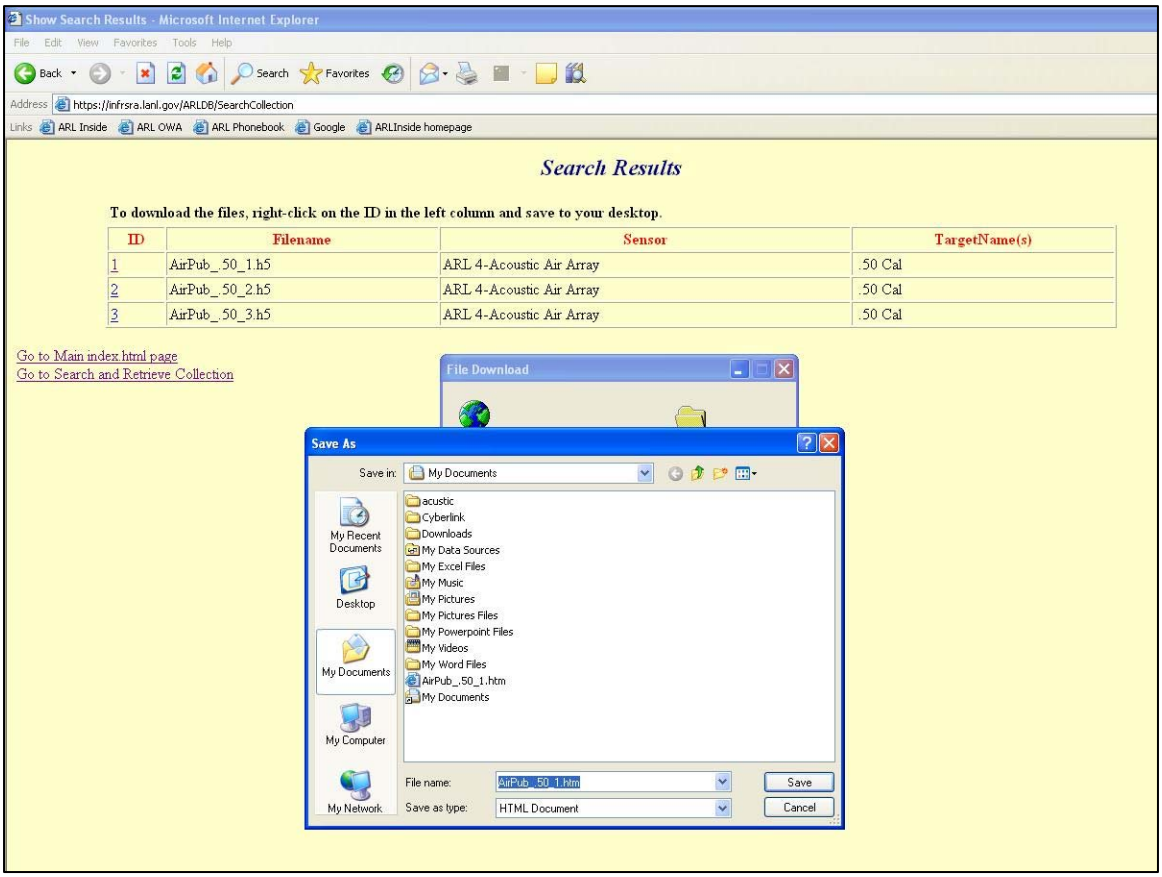

Figure 6. Dialog box for downloading signatures.

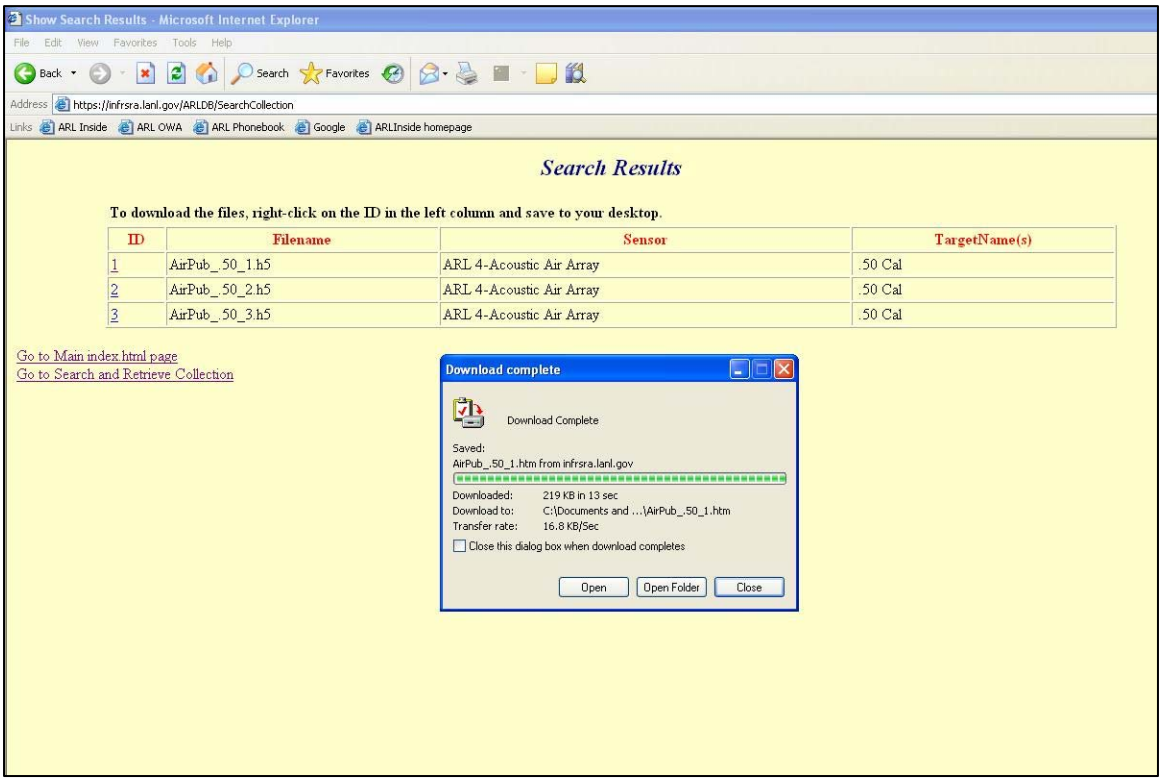

Figure 7. Dialog box showing completion of downloading operation.

The Web interface uses JSP for the presentation view of the Web application and Java servlets for the business logic behind the Web application. JSP allows the creation of dynamic Web pages that combine the static elements of HTML and dynamic elements of Java to access Java 2 Platform, Enterprise Edition (J2EE) services and application program interfaces (API) such as JDBC (Java Database Connectivity). Using Java and JDBC, custom designed database classes allow direct access to the database directly through the JSP. Java servlets provide session management and tracking of users. The combined use of Java servlets and JSPs provide scalability and portability across many platforms (*3*). The design allows the software to work with many operating systems, Web and application servers, and database servers.

6. HDF5 Database Signature

HDF5 is an object-oriented, open source, general-purpose, machine-independent, binary format developed by the National Center for Supercomputing Applications (NCSA) and is designed for storing large amounts of signature data of various modalities and complexity. NASA has used the file format for over 15 years to manage large amounts of imaging data (*4*). A single HDF5 multimodal signature file is capable of storing all the signature modalities and ancillary information into a single file, although consideration of the file size with respect to downloading times over the Web is necessary. Various signature models allow a given signature to meet the dissemination requirements for a given level of online dissemination. Many open source, platform independent, powerful viewing and plotting tools (HDFView and HDF Explorer) are available over the Web. These tools are easy to download and install on your computer and provide easy to use GUIs for easy viewing of the signature and ancillary information. The HDF group Web site (http://www.hdfgroup.org) allows open source downloading of several tools. MATLAB 7.x fully supports HDF5 files with several functions to create, write, and read HDF5 files. Seamless integration of HDF5 signatures into the MATLAB environment allows algorithmic developers and researchers the ability to use the data immediately after downloading the signature files.

The file format has many powerful features that make it the perfect solution for the dissemination of multimodal signature data. These features are:

a. Supports large, complex scientific and engineering data sets with both lossless and lossy compression capability and encryption, error detection, and user-definable filters (*4*).

b. Provides organization of data for efficient storage (*4*).

c. Provides parallel I/O, including Message Passing Interface (MPI) I/O for parallel environments, and remote access (*4*).

d. Provides the ability to store multimodal signature data including metadata.

e. Future standard file format (64-bit) for MATLAB, replacing the present MATLAB 32-bit binary file format (known as mat file) (*5*).

f. Seamlessly integrates with many development languages such as MATLAB, Python, Java, C/C++, and FORTRAN with full open source library support.

The HDF group Web site is an excellent source for additional information on HDF5.

Especially developed MATLAB codes create HDF5 signatures from existing database libraries and legacy databases (*6*). The MATLAB codes create different HDF5 signatures depending on the level of dissemination. Over 800 HDF5 signatures, including ground and air platform acoustic array data of small arms, mortar, artillery fire, C4 explosives, and multimodal signatures

of equipment related to human infrastructure, are presently available on the public release/unlimited dissemination Web site.

HDFView is an open source viewing and simple plotting tool developed for many different platforms including Windows, LINUX, and UNIX from the HDF group Web site. The GUI, as shown in figure 8, displays the entire contents (signature and ancillary information) of the HDF5 signature. Figure 9 demonstrates the plotting capability of the HDFView tool.

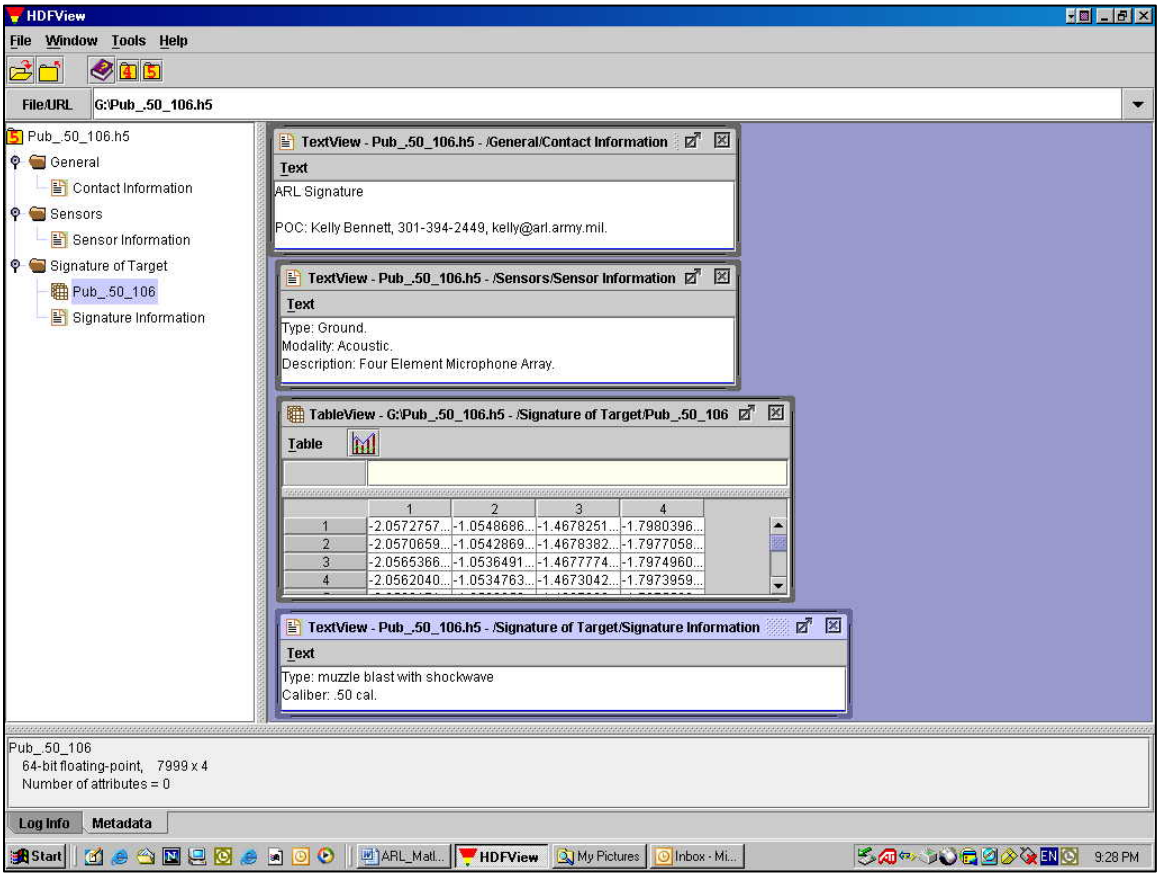

Figure 8. Visualization of a HDF5 multimodal signature using the HDFView tool.

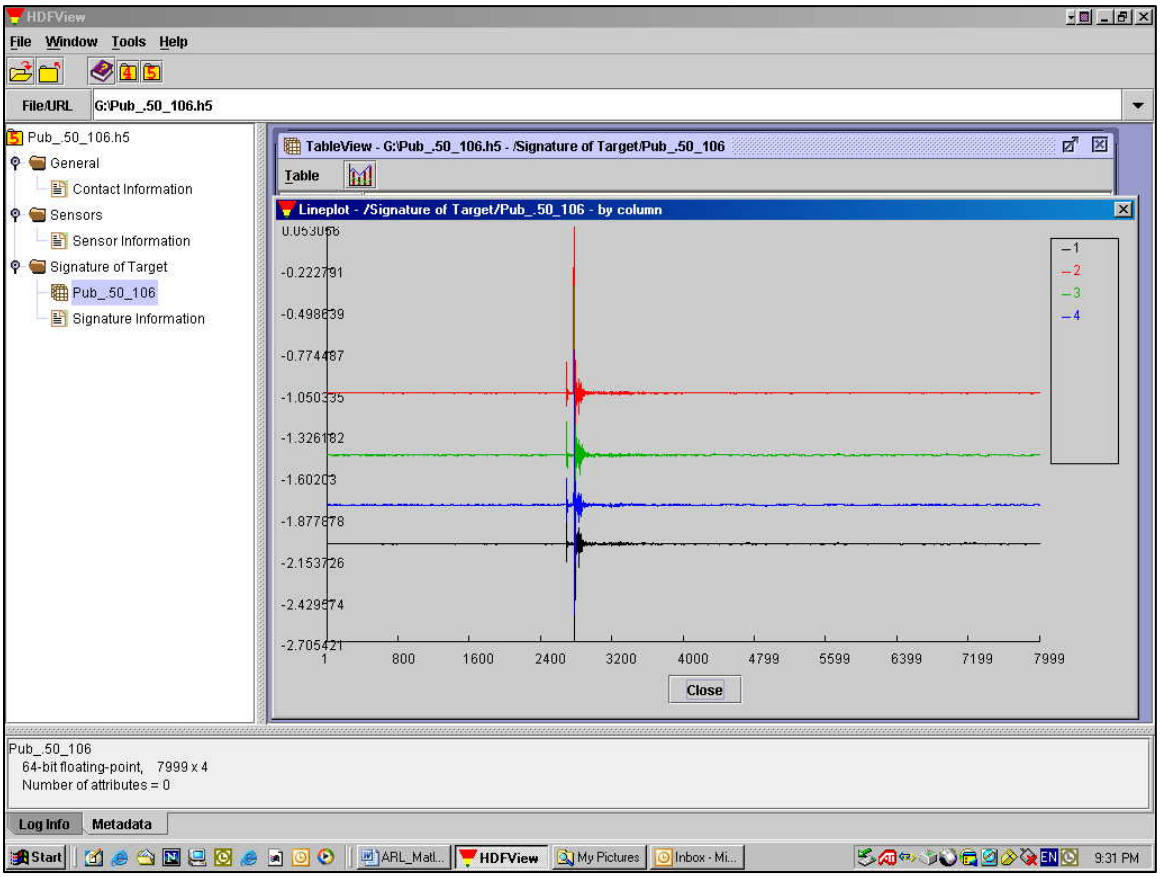

Figure 9. Simple plotting routine provided by the HDFView tool.

HDF Explorer is another open source, data visualization tool that available from the Space Research Software Web site (http://www.space-research.org/) for Windows only platforms. It is an excellent tool for visualizing the information inside a HDF5 multimodal signature, particularly imaging modalities.

HDF5 is a very flexible file format that will greatly aid the process of sharing signatures with ARL customers as well as supporting our internal research efforts within ARL.

7. Web Portal to a Computational Engine and HPC Resources

The Internet is a wonderful networking infrastructure to share database signature information. However, the concept of extending the Web interface into a portal system to share algorithms through a rich online interaction with a Web interface to a computational engine is very intriguing. Users would be able to access ARL algorithms with our data sets on a variety of computational engines, such as a MATLAB computational engine (*2*), and access to high performance computing resources would also be possible.

ARL is developing a next generation Web interface for access to a computational engine, such as MATLAB. The advanced interface is based on earlier efforts by Ohio State University (*2*) under the User Productivity Enhancement and Technology (PET) program and the DoD High Performance Computing Modernization Program (HPCMP) in support of ARL. The new interface will provide unequalled access to a centralized collection of sensor data of various modalities that are co-located and co-registered through dynamic Web pages designed specifically for research and development.

Conclusions

The multimodal signatures database is an integral part of the mission performed by ARL, SEDD and the SIP division in the development of target detection, tracking, and classification algorithms and systems. The multimodal signatures database, future computational engine, and algorithmic development environment over the Web will greatly enhance the development of algorithms for detection, tracking, localization, and classification, and vastly improve Intelligence, Surveillance, and Reconnaissance (ISR) in the battlefield through improved system performance. By leveraging the best open source software and Web technologies available, ARL has created a multimodal signatures database that is fully accessible over the Web. The database provides unparalleled interoperability, security, and sharing of our signature data with our customers, including U.S. Army Research, Development, and Engineering Command (RDECOM), other DoD agencies, intelligence communities, and the National Signatures Program (NSP).

ARL is leading the way in providing scientific visualization; internet access to scientific data; computational and algorithmic development environments and Web portals; innovative software and database design and methodologies; unique integration of algorithms, databases, and analytical tools; and leveraging open source software and database technologies and designs.

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Acronyms

API	application program interfaces
ARL	U.S. Army Research Laboratory
DBA	database administrator
DoD	Department of Defense
DREN	Defense Research Engineering Network
GUI	graphical user interface
HDF	Hierarchical Data Format
HDF5	Hierarchical Data Format 5
HPC	High Performance Computing
HPCMP	High Performance Computing Modernization Program
HTML	HyperText Markup Language
ISR	Intelligence, Surveillance, and Reconnaissance
J2EE	Java 2 Platform, Enterprise Edition
JDBC	Java Database Connectivity
JSP	JavaServer Pages
JWICS	Joint Worldwide Intelligence Communications System
LAN	local area network
LANL	Los Alamos National Laboratory
MMSDB	Multimodal Signatures Database
NCSA	National Center for Supercomputing Applications
NSP	National Signatures Program
OGA	other government agencies
OS	operating system
PET	Productivity Enhancement and Technology
RDECOM	U.S. Army Research, Development, and Engineering Command
SA	System administration
SEDD	Sensors Electron Devices Directorate
SIP	Signal Image Processing
SIPRNET	Secret Internet Protocol Router Network

SQL	Structured Query Language
SSL	Secure Socket Layer
WAN	wide area networks

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